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Medicine & Science

A cosmic view on ice

Neutrinos: A telescope that points into the icy depths of the South Pole is allowing scientists to study once elusive subatomic particles.

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Francis Halzen took nearly 10 million federal tax dollars, built a telescope at the South Pole and pointed it down instead of up.

To his relief, the telescope, once dubbed the "weirdest" on the planet, is working just fine, and Halzen reports, "It's like I've been let out of jail."

Halzen is a physicist at the University of Wisconsin and co-founder of the Amanda II project - an international effort to sink a telescope into the Antarctic ice to map the cosmic origins of sub-atomic particles called neutrinos.

The Antarctic Muon and Neutrino Detector Array looks "down" from the South Pole to study Earth's northern sky, using the Earth's mass to filter out everything but high-energy neutrinos from deep space.

Most neutrinos fly unimpeded through the planet and past Amanda's detector array. But one in a billion - about four each day - crash into protons or neutrons of water molecules in the ice, triggering fleeting trails of blue light.

Using the light's path through the detector array to calculate the neutrinos' trajectories, scientists can trace them backward to where they began their journey - thought to be some of the most violent places in the universe.

Last week Halzen and his team presented Amanda's first rough map of neutrino sources to scientists at a meeting of the International Astronomical Union in Sydney, Australia. Based on just the first year of data from Amanda, the map should become more precise as more neutrinos from two subsequent years of observations are analyzed.

The violent forces that create cosmic rays and other high-energy particles from outer space have long been a mystery. Those particles that could be detected traveled paths that obscured their origins, while neutrinos, which follow straight paths, couldn't be detected. Until now.

Karl Erb, polar programs director for the National Science Foundation, said Amanda's results provide "a tantalizing clue; if we learn more about where neutrinos come from, we will go a long way toward understanding the other particles."

Halzen's team hopes Amanda's map will lead scientists to the mysterious colliding black holes, dying stars, violent galactic cores and other such places where neutrinos likely are born.

Physicists and astronomers love the most violent neighborhoods of space. They've dreamed for decades of building a telescope that could reveal the "neutrino sky," just as the invention of radio telescopes, ultraviolet, infrared and X-ray telescopes has revealed other unexpected phenomena.

Neutrinos themselves were first theorized in the 1930s, but they're so elusive they went undetected until 1956.

Low-energy neutrinos are generated by nuclear reactors, the stars and the sun, and by cosmic rays striking the atmosphere. High-energy neutrinos are created by titanic events at vast distances from Earth.

One of the most abundant of the fundamental particles of nature, neutrinos are also some of the oddest. They have no electric charge and virtually no mass.

So, unlike light or charged particles such as protons and electrons, their paths are not bent by gravity or magnetic fields, or blocked by solid objects. That makes them intriguing to astronomers hoping to discover and map their origins.

But there's a catch. Just as they pass like ghosts through planets and people, neutrinos also zip through telescopes without a trace.

It turns out that a few neutrinos are occasionally stopped by head-on collisions with protons or neutrons in any atomic nuclei. Such collisions create another, heavier particle, called a muon, that gets shoved along the neutrino's path - like a car hit by a train.

In a clear medium such as water or ice, scientists discovered, those muons leave a fleeting trail of blue light that can be recorded by nearby detectors.

So, for decades, scientists have hunted down neutrinos in tanks of water, typically buried in abandoned mines or tunnels to ensure that no particles but neutrinos reach the detector.

But those detectors can spot only low-energy neutrinos such as those from the sun. Catching far rarer high-energy neutrinos from intergalactic space demands a much bigger device, shielded by the entire planet.

In 1987, Halzen proposed sinking neutrino detectors deep into the icecap at the South Pole, where it would be dark, stable and, best of all, cheap - at least as experiments in particle physics go.

Five years later, with $10 million - most of it from the National Science Foundation - scientists from institutions in America and Europe began construction of the largest high-energy neutrino detector ever built.

Working at the U.S. Amundsen-Scott South Pole Station during brief polar summers, Amanda crews used hot-water "drills" to melt shafts in the icecap. They bored 20-inch-wide holes, 1.2 miles through ice as old as 100,000 years.

Before water in a shaft could freeze again, the team slipped in a chain of bowling-ball-size "optical modules," strung together like beads along their data and power cables.

Amanda II now has 19 such chains with a total of 677 modules arrayed in a kind of cylindrical curtain more than a mile beneath the surface. The array is 550 yards tall and 220 yards in diameter.

After traveling through space, each neutrino streaks into Earth's northern hemisphere, through thousands of miles of rock and magma, only to crash into a proton in a water molecule at the South Pole.

Amanda's optical sensors record the intensity and timing of the flash, and computers on the surface reconstruct the neutrino's trajectory, tracing it backward to within one degree of its origin in the northern sky.

University of California physicist P. Buford Price said the team's vital measurements of the clarity of deep polar ice yielded novel data on its scant microbial life and layers of ancient volcanic dust. Their findings in biology, climatology and glaciology have been published in more than a dozen scientific papers.

Amanda scientists are planning a $250 million expansion of the telescope, deploying thousands of improved optical modules on 80 cables.

The more sensitive instrument, to be called IceCube, will monitor a full cubic kilometer of the polar ice and yield more precise maps of the neutrino sky. Construction is set to begin next year.